New Techniques for Fast Neutron Imaging and Spectroscopy

Completed Technology Project (2017 - 2020)

Project Introduction

Introduction: The detection of fast neutrons has important applications in a variety of fields including geospace, solar, and planetary physics. Though neutrons are ubiquitous products of nuclear interactions, they are challenging to detect and often suffer from large backgrounds. High-energy neutrons (> 50 MeV) pose even more challenges since the traditional double scatter technique based on a time-of-flight (ToF) is limited by the finite flight path and active detector sizes required by small satellite platforms. At these high energies, the proton recoil is likely to leave the detector volume, degrading the energy and angular resolution. Typically, double-scatter instruments are composed of two or more segmented scintillators. Scintillator-based technologies have a proven record for detecting and measuring fast neutrons. They have high stopping power, good energy resolution, and fast timing properties. Dramatically increasing the segmentation of scintillator arrays (down to hundreds of sub-micron fibers) enables the use of proton-tracking, effectively supplanting the ToF measurement, thereby eliminating the need for widely separated detectors. This greatly increases the detection efficiency. Modern readout devices such as multi-anode micro-channel plate/photomultipliers (MCP-PMTs) and silicon photomultipliers (SiPMs) offer an ideal alternative to photomultiplier tubes given their inherently compact size, fast response, and relatively low operating voltages. An instrument based on scintillating-fiber bundles would provide high-resolution imaging of fast neutrons at energies where the bulk of solar and magnetospheric neutrons resides. Methodology: The neutron/γ-ray spectrometer proposed is designed to measure >10 MeV neutrons and relies on the measurement of the momentum vector of the recoil proton associated with two interactions within a single scattering volume, e.g., the highly segmented fiber bundle. From a measure of the recoil momentum in two successive scatters, the energy and direction of the incident neutron can be reconstructed. Imaging neutron spectrometers have the distinct advantage of being able to reject the high background in space, further improving the signal-to-noise ratio. The instrument concept to be developed consists of orthogonally stacked scintillating fibers read out by new high-resolution MCP-PMTs. High-resolution MCP-PMTs, with <1 ns rise times, can be produced down to several hundred-μm resolution, offering for the first time, a viable option for neutron spectroscopy and imaging based on charged particle tracking. An MCP-PMT-based neutron imaging spectrometer is a significant improvement over earlier proton-tracking based technologies (Ryan et al. 1999; Miller et al. 2005; Legere et al. 2006; Muraki et al. 2012; 2013). The MCP-PMT can be read out in anode strips rather than in individual anodes significantly reducing the number of channels to process. Gamma-rays are distinguished from neutrons by the density along the electron ionization track and the track length. The proposed work will span three years. We will design and test a proof-of-concept instrument based on off-the-shelf 1.6 mm pitch MCP-PMTs from Photonis coupled to a fiber bundle (6×6×6 cm3) with orthogonal planes of 300-μm fibers. We will develop the readout for individual anode and strip

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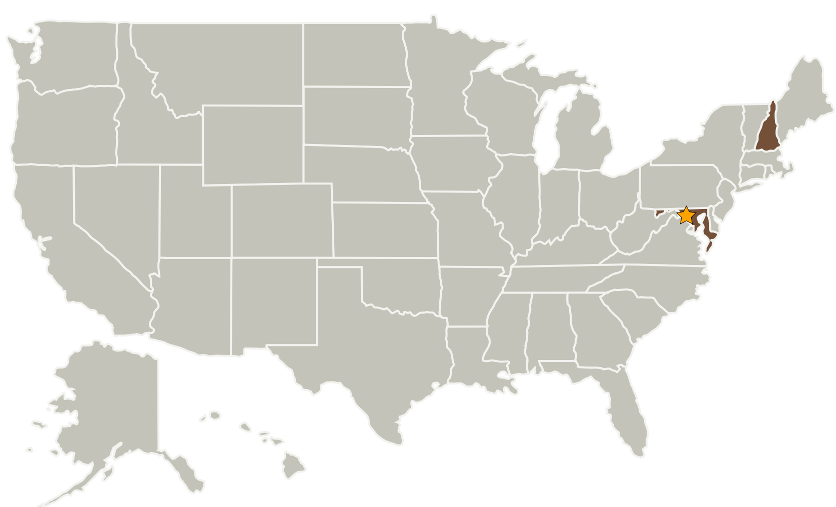
anode configurations, explore new, low-power ASICs for pulse height and time-to-digital conversion, and test in the laboratory and accelerator environments. Relevance: The technology development proposed addresses NASA's Heliophysics strategic objective in the SMD Science Plan "to understand the Sun and its interactions with the Earth and the solar system, including space weather." In addition, investigations of solar/magnetospheric neutrons on SmallSats would complement the current and upcoming missions of Van Allen Probes, Solar Probe Plus, Solar Orbiter, and IMAP.

Anticipated Benefits

Support NASA's strategic objectives to understand the Sun and its interactions with Earth and the solar system, including space weather. This will be achieved by developing/demonstrating instrumentation technology necessary to address the following science goals:

- Explore the physical processes in the space environment from the Sun to the Earth and throughout the solar system;
- Advance our understanding of the connections that link the Sun, the Earth, planetary space environments, and the outer reaches of our solar system;
- Develop the knowledge and capability to detect and predict extreme conditions in space to protect life and society and to safeguard human and robotic explorers beyond Earth.

Primary U.S. Work Locations and Key Partners



Organizational Responsibility

Responsible Mission Directorate:

Science Mission Directorate (SMD)

Lead Center / Facility:

Goddard Space Flight Center (GSFC)

Responsible Program:

Heliophysics Technology and Instrument Development for Science

Project Management

Program Director:

Roshanak Hakimzadeh

Program Manager:

Roshanak Hakimzadeh

Principal Investigator:

Georgia A De Nolfo

Co-Investigators:

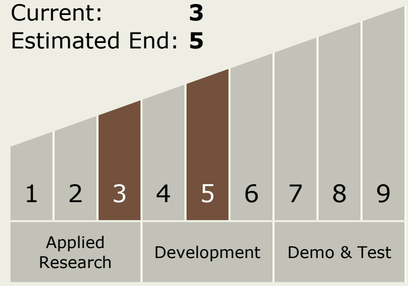
Peter F Bloser
David T Leisawitz
Mark Mcconnell
James M Ryan

Organizations Performing Work	Role	Type	Location
⭐Goddard Space Flight Center(GSFC)	Lead Organization	NASA Center	Greenbelt, Maryland

Primary U.S. Work Locations	
Maryland	New Hampshire

Technology Maturity (TRL)

Start: **3**
Current: **3**
Estimated End: **5**



Technology Areas

Primary:

- TX08 Sensors and Instruments
  └ TX08.3 In-Situ Instruments and Sensors
    └ TX08.3.1 Field and Particle Detectors

Target Destination

The Sun